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INITIAL ESTIMATES OF INTEGRATED MAINTENANCE INFORMATION SYSTEM (IMIS) COSTS AND BENEFITS VOLUME I: MAIN REPORT

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This report has been reviewed and is approved for publication.

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13 ABSTRACT *(Maximum 200 words)*

This report analyzes the system-wide costs and benefits of implementing the Integrated Maintenance Information System (IMIS) for the F-16. The Human Resources Directorate of the Armstrong Laboratory has undertaken IMIS as an Advanced Technology Transition Demonstration (ATTD) effort. ATTD efforts provide "proof-of-principle" demonstrations conducted at the system or major subsystem level in an operational environment. They demonstrate the potential of new technologies to provide significant improvements in cost-effectiveness. IMIS has the potential to provide major improvements in the efficiency of aircraft maintenance processes. This report documents the initial effort to develop a rough order of magnitude estimate of the functional costs and benefits of implementing the IMIS technology. Estimates are developed for the Base Case and two IMIS implementation alternatives. The alternatives are analyzed, results identified and conclusions reached.

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PREFACE

The Integrated Maintenance Information System (IMIS) has the potential to provide major improvements in the efficiency of the aircraft maintenance process. Volume I of this report documents the initial effort to develop a rough order-of-magnitude estimate of the system-wide automated data processing and functional costs and benefits of implementing IMIS capabilities. Volume II provides detailed analytic information for cost analysts. The effort was performed for Armstrong Laboratory, Human Systems Center, Brooks AFB, Texas, under the terms of contract F33600-85-D-7002, Task Order 91-001.

The Project Director was Dr. Burke Burright, Plans and Programs Directorate, Armstrong Laboratory (AL/XP). Dr. H. J. Clark, who until his retirement headed the Laboratory's Program Integration Division, ensured that the task statement and technical comments were clear. Dr. Carter Alexander, who heads the Plans and Programs Directorate, provided crucial support.

The Logistics Research Division, Human Resources Directorate, Armstrong Laboratory (AL/HRG), is carrying out IMIS's advanced development effort. Capt Bradley Lloyd served as the Assistant Project Director and technical contact at the Division. Capt Lloyd and Lt J. C. Bradford provided unflagging support in arranging and accompanying contractor visits, coordinating briefings, procuring data, and assembling technical comments. Their hard work significantly eased the Project Director's burdens and enabled the effort to succeed.

Others at the Logistics Research Division also made key contributions. Dr. Don Thomas provided early access to data from field demonstrations. Mr. Richard Weimer provided many useful comments. Mr. Bertram Cream, Chief, Logistics Research Division, and Mr. Robert Johnson, Chief, Operational Logistics Branch (AL/HRGO), provided continued support for the work.

Mr. Frank Sosa of the Human Systems Center's Cost Analysis organization provided a thorough sufficiency review for the analysis and made several suggestions to improve it.

The Alexandria Office of Robbins-Gioia, Inc., carried out the research. Principal analysts were Mr. Robert J. Tomasetti, Mr. A. Barry Calogero, Mr. Charlie E. Jones, Mr. Charles L. Hanna, Mr. Thomas J. Guarino, Mr. Leon E. Dimpsey, Ms. Marchelle A. White, Mr. Michael X. Cammisa, and Ms. Kimberly K. Hodak.

EXECUTIVE SUMMARY

Background

The Integrated Maintenance Information System (IMIS) is an Armstrong Laboratory advanced development program being conducted as an Advanced Technology Transition Demonstration. Its purpose is to demonstrate how an integrated maintenance information system, capable of replacing the current paper-based technical orders (TOs) and many cumbersome maintenance procedures, can improve the productivity of maintenance personnel.

As a 6.3 research program, IMIS is an attempt to develop and test technology to improve the performance of maintenance technicians and organizations. It is accomplishing this goal by providing fully integrated information to the technician at the work site. IMIS gathers and integrates pertinent technical information from the aircraft, pilots, TOs, technicians, and historical data systems. The technicians access the information via a hand-held computer information system called the Portable Maintenance Aid (PMA). Maintenance Information Workstations (MIWs) located at key points in the maintenance organization provide access to information for management functions.

The PMA allows users to access all pertinent maintenance information without having to interact directly with all the supporting systems. Step-by-step instructions are provided for troubleshooting, remove, replace, and repair tasks. The system automatically sorts the technical data for effectivity codes and records the maintenance actions for the historical database when the job is completed.

IMIS is comprised of three interdependent core capabilities: Interactive Electronic Technical Manuals (IETMs), connectivity with maintenance data systems, and dynamic diagnostics.

- <u>Interactive Electronic Technical Manuals</u>. IMIS will replace paper-based TOs with IETMs. This capability decreases repair times by giving maintenance personnel rapid access to relevant TO sections and by improving the presentation of technical data. It also eliminates the requirement to manually post TO changes.

- <u>Connectivity with Maintenance Data Systems</u>. IMIS will provide flight-line maintenance personnel with direct, electronic access to the Core Automated Maintenance System (CAMS) and the Reliability and Maintainability Information System (REMIS). IMIS will provide base-level maintenance data to CAMS, which will pass the information to REMIS. This capability eliminates paperwork, improves the accuracy of the data, and speeds up the current processes for recording and reporting maintenance data. It also provides managers with real-time access to maintenance reports, aircraft and work order status, and so forth. IMIS also provides access to the Standard Base Supply System (SBSS) via CAMS.

- <u>Dynamic Diagnostics</u>. IMIS will have integrated dynamic diagnostics based on symptom/fault and probabilistic methods as well as aircraft-specific historical information. For an aircraft with a maintenance bus, the PMA will plug into the bus

to operate built-in-tests (BITs), download system performance and status data, and dynamically determine the next diagnostic step based on the BIT data. The dynamic diagnostics capability substantially reduces maintenance troubleshooting time and the incidence of "retest OKs" (RTOKs) and "cannot duplicates" (CNDs). Reducing RTOKs decreases mobility readiness spares and pipeline spares requirements.

In addition to these core functionalities, the full IMIS concept includes other capabilities such as remote part ordering and training.

- Remote Part Ordering. This capability would enable maintenance technicians to order parts remotely without having to manually enter information such as part numbers on parts request forms. IMIS would accomplish this by using a radio link from the PMA to the MIW to interact with SBSS through CAMS.

- Training. The IMIS database, hardware, and tools offer many opportunities for use in training. By adding a training capability, IMIS would provide a continuing maintenance training capability on the flight line and in the work place. It would also allow simulated on-equipment faults to be diagnosed and repair actions to be identified.

Purpose

Field tests of IMIS technologies have shown significant efficiencies in aircraft maintenance. The F-22 and other operational and planned aircraft weapon systems have already adopted the IMIS concept. This study focuses on the financial and expected performance impacts of implementing IMIS on legacy aircraft weapon systems. The goal is to provide **initial** estimates of the incremental costs and associated benefits of the Core IMIS technologies. The study aims to provide credible, **rough order-of-magnitude (ROM) estimates** to guide decision-makers and program planners.

In addition to the Core IMIS capabilities, this study presents the costs and benefits associated with adding the Remote Part Ordering capability to the Core IMIS implementation option. This study does not quantitatively estimate benefits stemming from the training capability. The IMIS training concept needs to be defined in more detail before specific costs and benefits can be estimated. (Although training costs and benefits were not quantified, a discussion of the issues associated with using IMIS for training is presented in Appendix E which is contained in Volume II of this report.)

In order to study the potential impact of IMIS on legacy systems, the study focused on the benefits and costs of implementing IMIS for the F-16. The F-16 was studied first because large numbers of F-16s are already in the operational inventory and are expected to remain in the inventory for many years, and because additional data concerning IMIS's impact on F-16 operations will become available after IMIS is field tested with the 310th Fighter Squadron at Luke Air Force Base (AFB), AZ.

IMIS costs and benefits were evaluated vis-a-vis the projected maintenance environment without IMIS--the Base Case. Net life-cycle cost (LCC) savings were estimated by comparing

the cost to implement the IMIS alternatives to the reduction in operations and support (O&S) costs achieved by implementing IMIS.

Results

A conservative estimating approach was taken. "IMIS Benefits" are reductions in the F-16 O&S costs resulting from IMIS implementation. The cost, benefit, and LCC savings estimates (assuming an 8-year IMIS economic life) for Core IMIS and Core IMIS with a remote part ordering capability are given below.

IMIS Costs and Benefits (FY 93 Constant-Value Dollars)[1]

	Core IMIS	Core IMIS with Remote Part Ordering
Nonrecurring Cost	$170.3M	$174.4M
Recurring Cost	$59.2M	$60.2M
Total IMIS Cost	$229.5M	$234.6M
IMIS O&S Benefits	$903.8M	$938.2M
Net IMIS LCC Savings	$674.3M	$703.6M

The results of the study support the following conclusions.

IMIS is cost effective. Acquiring Core IMIS for the F-16 fleet and operating it for eight years would cost the Air Force about $229.5M (in FY 93 dollars). It would enable the Air Force to save $903.8M. As a result, it would generate a net savings on the order of $674.3M.

Fewer RTOKs and more productive maintenance personnel generate the largest IMIS benefits. Benefits related to reducing the number of RTOKs accounted for 32 percent ($284.7M) of the IMIS benefits. Eliminating the requirement to manually post TO changes accounted for 50 percent ($454.5M) of the IMIS benefits. The remaining 18 percent ($164.6M) is achieved through reductions in repair and maintenance troubleshooting time, reductions in TO research time, reductions in maintenance documentation time, reductions in Air Force Technical Order (AFTO) 22 Change Request preparation time, and reductions in the weight of the TOs required to support squadron mobility.

[1]Prior to the release of this study, interim results were published in a short technical paper entitled, *Integrated Maintenance Information System (IMIS) Initial Estimates of System-Wide Costs and Benefits: An Executive Summary* (Burright et al., 1993). The estimates contained in this final report update the results reported in the May 1993 technical paper by incorporating more recent operational data and by refining key assumptions.

PMA procurement, TO conversion, and recurring IMIS maintenance costs are the primary cost drivers. Procuring the PMA and converting F-16 paper-based TOs to IETMs are the largest nonrecurring costs. Together, they account for 77 percent of the nonrecurring cost. Repair and maintenance of the hardware and software for IMIS account for 85 percent ($50.5M) of the recurring costs. Together, these three cost elements compose 79 percent of the overall IMIS LCC.

The incremental costs and benefits for adding the Remote Part Ordering capability to the Core IMIS are both relatively small; however, the analysis suggests that the capability would provide net benefits. The largest cost associated with adding this capability is the radio frequency (RF) link between the PMA and the MIW. Adding this capability to Core IMIS would allow the maintenance technician to determine part availability and order parts remotely from the aircraft without having to complete part request forms or locate part numbers or national stock numbers. Although this study included an RF link for part ordering, many of the benefits associated with this capability can be realized through direct downloading of part-ordering information from the PMA to the MIW.

I. INTRODUCTION

Summary

The Armstrong Laboratory is conducting research and development on the Integrated Maintenance Information System (IMIS). Early tests of the IMIS concept show that increased efficiencies in aircraft maintenance are possible. Previously, no study had been conducted to systematically estimate the life-cycle costs (LCCs) and benefits associated with implementing IMIS technologies. The objective of this study is to provide initial estimates of incremental costs and the associated benefits of IMIS capabilities on legacy systems. All estimates in this study are rough order-of-magnitude (ROM) estimates and will be further refined as additional data becomes available.

This report is organized into two volumes. Volume I contains the body of the report. Section II outlines the current F-16 operational and maintenance environment and identifies areas that the authors believe could benefit as the result of IMIS. (The F-16 was studied first because large numbers of F-16s are expected to remain in the inventory for many years and because F-16 Block 42 aircraft are being used in the full IMIS field test at Luke Air Force Base [AFB], Arizona.) Section III presents two IMIS implementation alternatives. Section IV identifies the ground rules and assumptions that were used for the analysis. Section V presents the cost element structure and the estimating methodologies. Section VI discusses the results of the analysis, and Section VII summarizes the findings and discusses the conclusions.

Volume II contains the appendices. Appendix A provides an overview of previous and planned demonstrations of IMIS technology. Appendix B presents the cost element structure used to perform the study. Appendices C and D present the detailed cost element sheets for the Base Case and the IMIS alternatives respectively. Appendix E addresses the potential benefits of using IMIS for training, and Appendix F discusses the spreadsheet model built using the cost element sheets.

IMIS Background

The IMIS project is an advanced development program being conducted as an Advanced Technology Transition Demonstration. Its purpose is to demonstrate how an integrated maintenance information system, capable of replacing the current paper-based technical orders (TOs) and many cumbersome maintenance procedures, can improve the productivity of maintenance personnel. The improved information system will increase the performance capabilities of technicians, resulting in an increased sortie-generation capability. Final products of the IMIS program consist of functional specifications that define and describe the computer and information technology necessary to meet the following specific objectives.

- Integrate multiple maintenance information sources into a single, easy-to-use information system.

- Tailor information to meet the specific needs of the task and the technician.

- Eliminate time-consuming paperwork and tasks through automation.

- Improve on-aircraft diagnostics.

- Improve the quality of maintenance performance by taking advantage of the system's ability to interact with the technician.

- Maximize the utilization of available manpower resources by providing information in standard, generic formats independent of the source and supporting general technical capabilities at various skill levels.

- Provide on-the-job training aids for new systems and proficiency training on existing systems.

- Provide the capability to support maintenance performance in future scenarios of consolidated specialties.

- Improve the maintenance capability for dispersed operations by packaging the needed maintenance information into a highly portable, deployable system.

These IMIS concepts have evolved through the incremental development of demonstration hardware and software that were field tested using maintenance personnel and operational equipment. Appendix A lists the most recent significant test events. Information from these tests was used to refine and expand the IMIS concepts and develop initial IMIS specifications. Additional tests and demonstrations of IMIS technology, planned for the F-16, will be used to provide further program validation and performance pay-off metrics.

II. THE F-16 ENVIRONMENT

F-16 Force Structure

More than 1700 F-16 aircraft are assigned to active duty Air Force, Air Force Reserve, and Air National Guard units at over 50 locations worldwide (ASC/YPF, undated). F-16 wings are generally composed of one or more aircraft squadrons. Since the squadron is the basic deployment unit of assignment, it is used as the basic unit for this analysis.

The size of the squadron may vary depending on the mission of the unit to which it is assigned. However, for this analysis, the number of aircraft per squadron was assumed to be either 18 or 24 aircraft. These numbers were determined from F-16 System Program Office supplied F-16 worldwide assignment data. (The process used to determine the number of F-16 squadrons from the F-16 worldwide assignment data is documented in Appendix C.)

In the recent past, a typical F-16 wing had full on-equipment and off-equipment maintenance facilities. F-16 squadrons now operate under the two-level maintenance concept (organizational- and depot-level only). Policy changes eliminated most of the off-equipment

intermediate shops, thereby moving that workload to the depot repair facilities. A pure two-level maintenance concept is assumed for this study.

F-16 Maintenance Activities

On-equipment (organizational) maintenance is the scheduled or unscheduled maintenance normally completed on the flight line. Maintenance time can be broken down into six major activities: researching, troubleshooting, communicating, repairing, documenting, and waiting (unproductive time spent awaiting information, parts, etc.). Maintenance procedures are essentially the same in combat as in peacetime. Figure 1 presents a breakout of the typical maintenance technician's time by activity.[2]

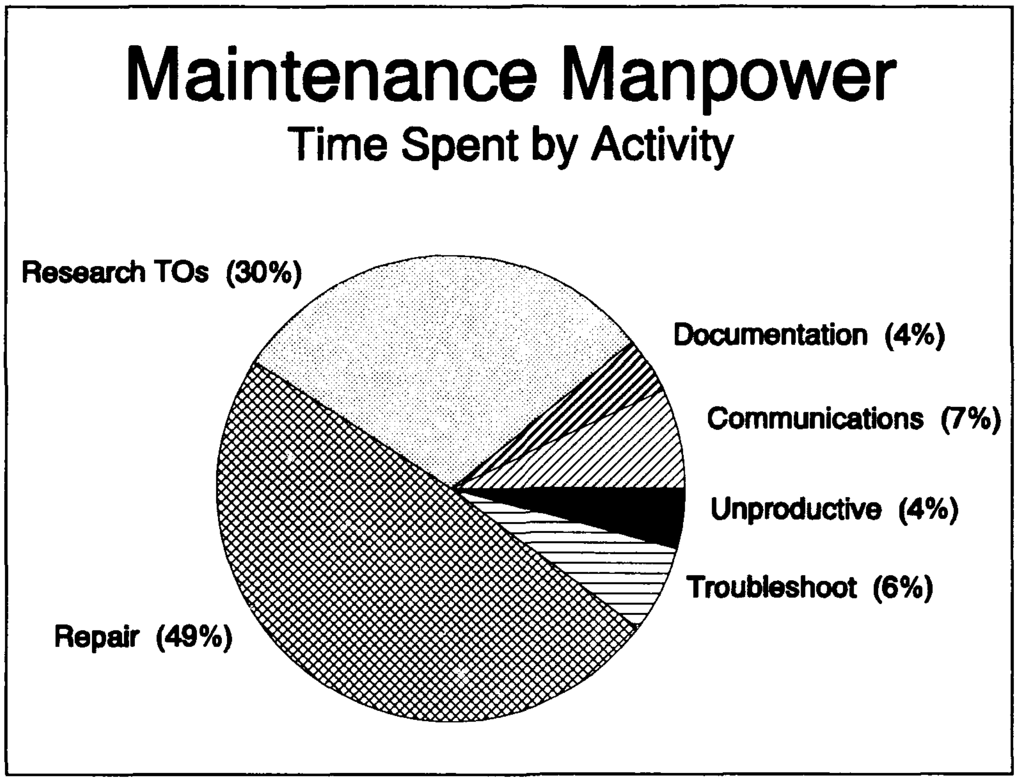

Figure 1
Maintenance Manpower Labor

[2]The breakout of maintenance technicians' time displayed in Figure 1 was derived from data presented in the *AFTOMS Feasibility Study: Final Report* (Dept. of Transportation, 1989) and the *Maintenance Task Timelines for the Integrated Maintenance Information System: Final Task Report* (Fischer et al., 1986). A detailed summary of the derivation is contained in Volume II, Appendix B under the discussion of C.E.S. NO. 3.2.2.2.1.

For this study, the maintenance activities identified in Figure 1 are categorized into four functional areas: TO Usage, Aircraft Maintenance and Diagnostics, Information System Interaction, and Part Requisition. Each of these groups is discussed below.

Technical Order Usage

F-16 maintenance technicians currently use the paper-based technical order system. These paper-based TOs are becoming larger, more complex, and more difficult for the technicians to use. They are also expensive to deploy and difficult to use in harsh weather conditions (Link et al., 1987).

Because of their complexity, TOs require many changes. For example, there was an average of 10.5 changes for each of the 3,062 F-16 TOs for the F-16 in fiscal year 1990 (FY 90) (JUSTIS, 1990). These changes are transmitted to field activities as paper packages containing instructions to remove and replace affected pages and, occasionally, to annotate new information with pen and ink. TO changes require approximately 0.5 hours to post (remove, replace, or annotate) for each copy (JUSTIS, 1990). This process is repeated hundreds of times throughout the Air Force for each TO. In addition, this manual updating of the paper-based TO system is subject to errors.

This study categorized TO usage into three activities: researching, TO changes, and weapon system configuration.

Researching. Technicians must research multiple TOs before attempting to diagnose and repair a malfunction. This is important because procedures differ depending on the peculiarities (e.g., differences resulting from modifications) of each aircraft. As shown earlier in Figure 1, 30 percent of the direct maintenance hours are expended in researching TOs (Department of Transportation, 1989).

TO Changes. Technicians report TO discrepancies with a paper form (Air Force Technical Order [AFTO] 22). The AFTO 22 is also used to submit suggested improvements to maintenance procedures. Because of the time required to prepare the forms and substantiate the suggestions, many discrepancies and suggestions are never submitted by the technicians. Additionally, AFTO 22 forms are processed manually by the submitter's work supervisor and later by the TO distribution office where each AFTO 22 submitted takes approximately one hour to process (JUSTIS, 1990).

Weapon System Configuration (General Dynamics Electronics, 1990). Technical data is required to configure an aircraft for a given mission. Configuring the aircraft for a specific mission may involve fuel tanks, Electronic Counter Measure (ECM) dollies, ECM pods, bomb lifts, munitions, suspension devices, munitions handling adapters, tools, support equipment, and fuel servicing equipment. Technical data from several TOs may be required to properly configure each aircraft.

Aircraft Maintenance and Diagnostics

Technicians isolate and eliminate the cause of aircraft malfunctions by using detailed fault isolation trees, test equipment, and repair procedures. The speed and accuracy of the diagnostic process depend on the experience of the technician, the level of difficulty of the specific problem being diagnosed, and the complexity of the TOs. Required information is usually dispersed throughout several TOs and can be difficult to find. As a result, the troubleshooting and repair processes are often time consuming. The problem is likely to be compounded by the fact that fully qualified technicians or battle damage assessors may not always be available during combat and/or at a deployed location (Link et al., 1987).

This study categorized aircraft maintenance and diagnostics into two activities: troubleshooting and repairing.

Troubleshooting. Troubleshooting involves actions to isolate a specific cause of a reported malfunction. TOs used to isolate faults often do not include troubleshooting techniques, and those which do are rigidly structured and do not adapt to various circumstances and available symptom information (Link et al., 1987).

Nondefective line replaceable units (LRUs) originally diagnosed as defective are also frequent problems. These LRUs are called "retest OK" (RTOK) items. A RTOK is an LRU that is diagnosed as defective, removed from the aircraft, and sent to the maintenance depot where it checks out satisfactorily. As a result, time and resources are expended in finding that the unit is not defective. In addition, RTOKs place increased demands on the supply system. The result is the purchase of items for the supply pipeline and for Mobility Readiness Spares Packages (MRSPs) that are unnecessary.

Maintenance actions recorded as "cannot duplicates" (CNDs) are also frequent problems. In the case of CNDs, maintenance technicians cannot duplicate faults that the pilot reported.

Repairing. The repair process consists of actions required to eliminate the cause of the malfunction (e.g., remove a defective part and replace with a nondefective part, calibrate, clean, etc.). TOs provide instructions to perform repairs. Unfortunately, TOs do not include integrated repair procedures. As a result, several different TOs are needed to perform some repair actions. Additionally, technicians must identify TO procedures that apply to their particular aircraft. This is done by filtering the effectivities associated with the aircraft tail number.

Information System Interaction

To maintain historical databases, maintenance technicians are required to document specific information about each repair they perform. For study purposes, the time they expend <u>documenting</u> repairs is included under "information system interaction" because they document repair information by inputting it into the Core Automated Maintenance System (CAMS). Examples of information that must be recorded are: employee number, skill level, job control number, work center number, elapsed time of repair, work unit codes, malfunction codes, and

repair narratives. Once the repair information is input into CAMS, it is then passed to the Reliability and Maintainability Information System (REMIS).

Part Requisition

Maintenance technicians also use CAMS to access the Standard Base Supply System (SBSS). Ordering a part is initiated by filling out a requisition for the replacement part. A specific part number, national stock number (NSN), figure, and index are the minimum maintenance information normally needed. Considerable time is consumed looking up and verifying this information. In addition, since no direct communications link exists between the supply system and the technician, valuable time is often lost sending the part requisition to supply, then waiting for the subsequent delivery or back-order notification. If the part is not available, a decision is sometimes made to cannibalize another aircraft for the part. This results in two repair actions (i.e., removing a part from one aircraft and then placing the part on another aircraft).

The "part requisition" functional area includes the effort to communicate with the base-level supply system to requisition replacement parts. The effects of slow system responses are also included, such as unproductive time spent waiting for information on parts and additional repair time resulting from cannibalization of aircraft.

III. ALTERNATIVES

In this section, four IMIS capabilities are combined into two alternatives, Core IMIS and Core IMIS plus Remote Part Ordering. The aim is to provide a general overview of the IMIS alternatives for decision-makers. Required resources and costs for each alternative are discussed. The analysis of these alternatives is described in Sections V and VI.

Core IMIS

Core IMIS is comprised of three interdependent capabilities: Interactive Electronic Technical Manuals (IETMs), Maintenance Data System Connectivity, and Dynamic Diagnostics. IETMs provide the foundation for IMIS. IMIS diagnostics require IETMs and connectivity to maintenance data systems. Key areas where IMIS will improve maintenance performance (e.g., improving the efficiency and accuracy of repair and troubleshooting tasks) rely on all three capabilities. Additionally, all three capabilities have essentially the same hardware requirements.

Requirements for Implementation of Core IMIS

The list below presents the primary requirements necessary to implement Core IMIS and thereby achieve the benefits described in this report.

- Current base-level TOs must be authored or converted to IETMs. Presentation software is also required to display the technical information to the maintenance technician.

- Portable Maintenance Aids (PMAs) and Maintenance Information Workstations (MIWs) must be fielded. PMAs and MIWs provide the maintenance technician with the means to interact with IMIS. MIWs provide the means to download relevant TOs to cartridges to be subsequently displayed on PMAs for maintenance tasks. MIWs (with the appropriate software) provide the interface with maintenance data systems and the base TO library.

- Interface development and maintenance of integration software is required for the interface with CAMS. Through CAMS, IMIS will access SBSS and REMIS.[3]

- Diagnostic software which generates diagnostic procedures and integrates IETMs, maintenance information, and other data is required.

[3]The authors recognize the uncertainty surrounding what will be the future maintenance management information system. Regardless of whether it is CAMS, TICARRS (Tactical Interim CAMS and REMIS Reporting System), or some other system, IMIS will interface to it. CAMS is referenced here because it is the current information system used by F-16 maintenance technicians.

- Self-contained tutorial software is required to instruct maintenance personnel in the use of the IMIS system.

- Initial training is required during IMIS installation. Thereafter, maintenance personnel will use the IMIS self-contained tutorial system to become proficient in the use of IMIS.

Benefits of Core IMIS

Initial tests of IMIS technology have shown that fielding Core IMIS will provide benefits in the functional areas identified in the previous section. One of the primary benefits of IMIS is that it has the potential to substantially reduce maintenance time. The benefits of this reduction were estimated in terms of the economic impact; however, the reduction in maintenance time could also improve aircraft mission capable rates.

Technical Order Usage.

- IETMs eliminate the need to maintain a paper-based TO library at the flight line.

- IETMs will reduce the time required to research TOs by 50 percent (Carlson et al., 1992).

- IETMs will improve the maintenance capability for dispersed operations by packaging the needed maintenance information into a highly portable, deployable system.

- IETMs will facilitate the origination and processing of suggested changes to maintenance procedures (AFTO 22s).

- IETMs will allow technical information to be presented at different skill levels, depending on the expertise of the maintenance technician. The presentation of technical information at different levels contributes to the IMIS objective of providing the capability to support maintenance performance by technicians in consolidated specialties.

- IMIS will essentially eliminate the need to print TOs. At locations where the F-16 is the only assigned aircraft, the majority of the printers and the associated lease, maintenance, and consumable costs could be eliminated.[4]

[4]Although TOs are currently delivered in paper-form to the base consolidated technical order distribution office, this study assumed that the capability to electronically deliver TOs to each base will be available at the time of IMIS implementation. Therefore, with IMIS, the need for printers and so forth at the base will go away.

Aircraft Maintenance and Diagnostics.

- Early demonstrations of IMIS indicate the potential for substantial reductions in troubleshooting time (Carlson et al., 1992). IMIS also has the potential to reduce CNDs.

- IMIS has the potential to substantially reduce RTOKs by improving the accuracy of on-equipment troubleshooting. Studies evaluating the use of automated diagnostic aids have consistently demonstrated large reductions in RTOKs (as high as 100 percent).[5] For this study, the reduction in false-removal rates and, thereby, reduction in RTOKs, was conservatively estimated at 30 percent. As a result of reducing RTOKs, maintenance manpower is reduced at both the base and depot. Transportation costs are reduced as well.

- IETMs have the potential to reduce the repair time for maintenance actions by 42 percent by automatically presenting maintenance technicians with the relevant steps during a repair action.[6]

- In addition to reducing maintenance manpower requirements, reducing RTOKs will also reduce pipeline spares and MRSP requirements.

- Because IMIS will reduce the incidence of repair actions through improved diagnostics and repair procedures, it also has the potential to reduce maintenance-induced faults.

- In a combat environment, dynamic diagnostic assistance will be particularly effective in the assessment and repair of aircraft battle damage. The diagnostic capability will also facilitate the consolidation of specialties by improving the effectiveness of technicians with less experience.

Information System Interaction.

- IMIS will integrate multiple maintenance information sources into a single, easy-to-use information system. It will enable technicians to access base-level data systems without having specialized knowledge of the systems' operation. More specifically, IMIS will eliminate or reduce the need to manually enter repair action data into CAMS.

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[5] For detailed information on the effectiveness of electronic diagnostics refer to the following reports: *Troubleshooting Performance Using Paper and Electronic Documentation*, Navy Personnel Research and Development Center, NPRDC TN 87-41; and *A Comparative Assessment of Paper-based and Computer-based Maintenance Information Delivery Systems*, Navy Personnel Research and Development Center, NPRDC TN 88-14.

[6] This value was determined from Table E-3 contained in *Maintenance Task Timelines for the Integrated Maintenance Information System - Final Task Report* (Fischer et al., 1986).

- IMIS provides managers with real-time access to reports for analysis of failure trends, excessive maintenance costs, and quality problems.

- The accuracy of data entered in various logistics systems should increase with the implementation of IMIS. This type of data is currently used throughout the Air Force for complex analytical work (e.g., requirements computation) and reporting (e.g., weapon system operating and support cost reports to the Office of the Secretary of Defense [OSD] and Congress). More accurate data will provide better decision-making information to all users.

Core IMIS plus Remote Part Ordering

This additional capability allows the technician to order parts and obtain part availability information from the flight line without having to complete time-consuming paperwork. It also relieves maintenance personnel from having to locate part numbers or NSNs in TO tables or microfiche readers.

Requirements for Remote Part Ordering

In addition to the Core IMIS requirements, a radio link is required between the PMA and MIW, including antennas, transmitters, receivers, and appropriate communication software. The PMA/MIW already has the necessary parts-ordering functionality through the MIW/CAMS interface.

Benefits of Remote Part Ordering

Because the maintenance technician is no longer required to research part numbers or enter the data into part requisitions, maintenance times and the potential for the input of invalid or incorrect part numbers are reduced. The reduction in turnaround time in part ordering reduces unproductive time and influences decisions to cannibalize other aircraft. This capability contributes to the IMIS objective of integrating multiple maintenance information sources into a single, easy-to-use information system.

IV. ANALYTICAL ASSUMPTIONS

Ground Rules

a. The estimates developed in this analysis are ROM. The risk and uncertainty of the estimates are by definition an "order of magnitude."

b. Costs and benefits are analyzed in three categories: research, development, test, and evaluation (RDT&E); investment; and operations and support (O&S). All costs associated with the IMIS Advanced Development Program are treated as sunk costs.

c. In order to facilitate analysis of the cost and benefits of implementing Core IMIS on the F-16 fleet, it is assumed that the Air Force will develop a competitive request for proposal (RFP) and perform a source selection. The notional contract award date is 1 Oct 94.

d. This analysis is centered on a base-level IMIS implementation. However, the impact on depot-level repair costs is considered.

e. IMIS must operate in all conditions ranging from normal peacetime operations to contingency/wartime operations.

f. IMIS will use both classified and unclassified TOs and other maintenance data.

g. This analysis was prepared using DoD Instruction (DODI) 7041.3 and Air Force Regulation (AFR) 173-15, *Economic Analysis and Program Evaluation for Resource Management*. Further information will be derived from the Office of the Assistant Secretary of Defense (OASD), Program Analysis and Evaluation (PA&E), *DoD Automated Information System Life Cycle Cost and Benefits Estimation Guide* (30 May 89) and the Air Force Cost Center's *Major Automated Information System Cost Estimating Guide* (AFCSTCP-1, March 1989).

h. Costs and benefits are discounted using time value of money analysis guidance in the Office of Management and Budget (OMB) Circular A-94, DODI 7041.3, and AFR 173-15.

i. The principal cost factor sources are AFR 173-13, *Air Force Cost and Planning Factors Guide*; Defense Communications Agency (DCA) Circular 600-60-1, *DCA Cost and Planning Factors Manual*; and Air Force Logistics Command (AFLC) Pamphlet 173-10, *AFLC Cost and Planning Factors Guide*.

j. The cost element structure (CES) defined in AFCSTCP-1 is used and tailored to satisfy the IMIS estimating requirements.

k. OSD inflation rates dated 3 March 1993 are used for this analysis.

Functional Assumptions for an F-16 IMIS Application

General Assumptions

a. IMIS is deployed worldwide to all F-16 squadrons.

b. IMIS will operate seven days per week, 24 hours per day. The Air Force will own and operate the hardware, system software, and application software. All hardware and software maintenance will be performed by contractors.

c. IMIS systems have a backup capability through the deployment of multiple MIWs and PMAs at each squadron. One MIW performs an additional function as a backup to the main MIW server. Overall, 14 MIWs are required per squadron: two stationary (file server and backup), one dispersed operating location (DOL) configured, one mobile configured, eight for management purposes, and two for handling classified TOs. The basis of issue for the PMA will be 3.7 per F-16 primary authorized aircraft (PAA) in a 24-aircraft squadron and 3.8 per F-16 PAA in an 18-aircraft squadron. These values are obtained by using the following assumptions: 3.2 PMAs per PAA in a squadron (Hanna, 1991), five PMAs per squadron for handling classified TOs, and six additional PMAs per squadron for training in the use of IMIS.

d. IMIS uses existing assets whenever feasible and economical. IMIS makes maximum use of current contracts, off-the-shelf hardware, and commercial off-the-shelf (COTS) software.

e. Each squadron will require five classified PMAs for storage and presentation of classified TO data. Two MIWs (one primary and one backup) will be required at a central location (such as an air logistics center [ALC]) for generating updated PMA cartridges. It is assumed that a secure operating system will not be developed for IMIS. The classified PMAs will be stored in a secured area, and will be the only PMAs on which classified data will be available. Classified PMA cartridges will be sent to each squadron, following standard classified data handling procedures. The classified MIWs will likewise be kept in a secure location and will be the only MIWs used for classified data.

f. Training is accomplished to support activities during the RDT&E, Investment, and O&S phases of the program. While some training may be classroom-oriented, most of the users (maintenance technicians) will receive tutorial training via the PMA. The general requirements for training in each phase are described below.

- <u>RDT&E</u>. IMIS training costs in this phase are for developing IMIS specific training courses and materials. An initial "cadre" which will participate in system test and evaluation will be trained during the development phase. IMIS program office personnel who may need additional training to perform their responsibilities during reviews, audits, and testing will receive training through existing Office of Personnel Management (OPM) funded professional career development training courses as required.

- <u>Investment</u>. All F-16 maintenance personnel will be trained during this phase of the program. The remainder of the training cadre is trained during this phase.

- O&S. Recurring training is based on current service practices. Specific training requirements will be identified by a Training Work Group (TRWG) composed of one representative from each Numbered Air Force with F-16s assigned and two representatives from the IMIS program office.

g. The F-16 squadron is the basic operational unit for the study. Based on F-16 World Assignment data provided by the F-16 program office, 71 F-16 squadrons were assumed. The number of aircraft per squadron was assumed to be either 18 or 24 aircraft.

h. This study assumes a pure two-level (Organizational and Depot) maintenance structure.

i. Additional personnel are not required to operate and maintain IMIS.

j. There is no requirement for additional base support facilities.

k. The cost to convert existing F-16 paper-based TOs to IETMs is conservatively based on the costs incurred to convert TOs for laboratory F-16 and F/A-18 demonstration efforts.

Technical Assumptions

a. As indicated in Table 1, installation of IMIS equipment is assumed to take approximately six quarters. For sites with more than one squadron, IMIS is implemented at all squadrons simultaneously.

IMIS Site/Squadron Installations by Quarter								
		Q1	Q2	Q3	Q4	Q1	Q2	Total
CONUS (Active)	Sites	3	4	3				10
	Squadrons	*9*	*10*	*5*				*24*
Air Force Reserve	Sites	3	2	1	1			7
	Squadrons	*3*	*2*	*1*	*1*			*7*
Air National Guard	Sites	1	1	3	7	8	6	26
	Squadrons	*3*	*2*	*3*	*7*	*8*	*7*	*30*
USAFE	Sites		2					2
	Squadrons		*4*					*4*
PACAF	Sites		3	1				4
	Squadrons		*5*	*1*				*6*

Table 1. IMIS Site/Squadron Installations

b. The quantity of lines of code developed for the IMIS prototype, written in C++ programming language, is analogous to the lines of code which would have been generated in the Ada programming language for the same functionality. The estimated software development effort in Ada for full functionality was extrapolated from the prototype development effort using equations from Dr. Barry Boehm's Ada Constructive Cost Model (COCOMO).

c. Weapon System Interfaces exist for diagnostic capabilities and provide access to on-board built-in-test (BIT). On-equipment diagnostics have fault isolation through BIT coverage, fault occurrence, environmental, and system configuration data.

d. It is assumed that an infrastructure to support electronic delivery of IETMs will be created by a program other than IMIS (i.e., JCALS) and will be in place by the time IMIS is implemented. The cost of creating this infrastructure, therefore, is not a part of the IMIS costs.

e. Current base-level Local Area Networks (LANs) are used for access to automated maintenance and supply systems.

f. IMIS uses an independent verification and validation (IV&V) contractor.

Cost Estimating Assumptions

a. FY 93 is the IMIS Program base year. The model uses FY 93 constant dollars.

b. The economic life of IMIS is eight years from full operational capability (FOC), which is the implementation of IMIS at the last F-16 squadron.[7]

c. The life-cycle phases used to develop the IMIS cost estimate are RDT&E, Investment, and O&S.

d. Commercial pricing can be based on DATAPRO or similar catalogs if end item pricing is not available through the General Services Administration (GSA) Authorized Automated Data Processing (ADP) Schedules, requirements contracts, or other Government contract vehicles.

e. A discount factor of 4.3 percent (midyear) is assumed to provide an accurate initial present value analysis of costs and benefits.[8]

f. Some estimated benefits reflect productivity improvements. More detailed analyses at the task and skill level are required before using the ROM estimates in this report to adjust actual budgets.

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[7] This is consistent with AFR-26-1, Vol. I, Attachment 2, Federal Stock Class 7010.

[8] This is consistent with the 29 October 1992 Revision of OMB Circular A-94.

V. COST AND BENEFIT ESTIMATING METHODOLOGY

This section presents the methodology used to quantitatively estimate the costs and benefits associated with fielding the IMIS alternatives. It displays the CESs and the estimating methodologies applied. The cost- and benefit-estimating methodologies presented in this section represent current IMIS information and data. Methodologies will likely change as IMIS program elements become better defined and additional data become available.

Cost Estimating Methodology

The cost-estimating methodologies for the IMIS alternatives are discussed in this section. A CES is included to address the LCC considerations for each alternative. The CES was developed by tailoring the information in Military Standard (MIL-STD) 881-A, *Work Breakdown Structures for Defense Material Items*; the Air Force Cost Center's *Major Automated Information System Cost Estimating Guide;* and the OASD/PA&E *DoD Automated Information System Life Cycle Cost and Benefits Estimation Guide*. The IMIS CES contains functional cost elements needed to determine quantifiable IMIS benefits and to support reporting requirements for an OSD-directed Business Case Analysis.

Research, Development, Test, and Evaluation Costs

RDT&E includes all costs required to develop the IMIS system before committing it to production. The RDT&E cost elements (as shown in Table 2) encompass the costs of engineering design, manufacture of test articles, and testing to prove the design. Table 3 highlights the methods used to estimate RDT&E costs. (Appendix B contains detailed definitions for each of these cost elements.) The following paragraphs provide more detail about the estimating methodology used for each cost element.

IMIS COST ELEMENT STRUCTURE

1.0 RESEARCH, DEVELOPMENT, TEST AND EVALUATION (RDT&E)

1.1 SYSTEMS ENGINEERING/PROGRAM MANAGEMENT

1.2 PRIME MISSION EQUIPMENT
- 1.2.1 Portable Maintenance Aid (PMA) Equipment
- 1.2.2 Maintenance Information Workstation (MIW) Equipment

1.3 PROTOTYPE

1.4 SOFTWARE
- 1.4.1/2 Interactive Electronic Technical Manauls (IETMs) Capability
- 1.4.3 Maintenance Data System Connectivity
- 1.4.4 Dynamic Diagnostics
- 1.4.5 Reserved
- 1.4.6 Independent Verification and Validation (IV&V)

1.5 SYSTEM INTEGRATION, TEST, AND EVALUATION (SIT&E)

1.6 DATA CONVERSION

1.7 DATA

1.8 TRAINING
- 1.8.1 Training Course Development
- 1.8.2 Training Manuals
- 1.8.3 Maintenance Training Course

Table 2. RDT&E Cost Element Structure

IMIS RDT&E Cost Element Structure

1.0 RDT&E	
1.1 SYS ENG/PROG MGMT	Engineering Estimate
1.2 PRIME MISSION EQUIPMENT	Analogy/Experts/Catalogs
1.3 PROTOTYPE	Actuals
1.4 SOFTWARE	
1.4.1/2 IETM Capability	Analogy/Experts, Ada COCOMO
1.4.3 Maint. Data System Connectiv	Analogy/Experts
1.4.4 Diagnostic Module	Analogy/Experts
1.4.5 Reserved	N/A
1.4.6 IV&V	COCOMO Factor
1.5 SIT&E	Factors (REVIC)
1.6 DATA CONVERSION	Analogy
1.7 DATA	Factors (DCAC 600-60-1)
1.8 TRAINING	Analogy/Experts/Factors

Table 3. RDT&E Cost Estimating Methodologies

Systems Engineering/Program Management. Systems engineering/program management (SE/PM) costs are estimated by performing an engineering estimate of the staffing levels required to support the program. The staffing levels include the identification of skill types and quantities of resources required to support IMIS development. This includes participation in reviews and audits and the execution of business and technical management functions in the program office. Manpower, travel, and contractor support costs are estimated in this element. The staffing levels are based on current IMIS program office forecasts for the IMIS demonstration system effort, which is analogous in size and complexity to the development of the IMIS production capability.

Prime Mission Equipment. The primary prime mission equipment (PME) hardware development effort for this phase is to mature the prototype design and build test articles. MIW equipment is primarily COTS hardware. The PMA is a new design containing some COTS components. The primary PMA cost includes efforts to design, integrate, test, and document a production design of this component. Cost data from similar previous efforts is used to estimate the costs.

Prototype. The IMIS demonstration system was developed and demonstrated to show the feasibility and functionality of IMIS in an actual F-16 maintenance environment. The effort included the development of prototype designs for the MIW and PMA hardware and software. The costs for the prototype are considered as sunk costs for the analysis.

IMIS Software. The IMIS demonstration system software for the presentation system, diagnostic system, and content data model is all programmed using C and C++ programming languages. The IMIS development software will be developed using the Ada language. "Research indicates that there is a direct correlation between Ada applications and overall object-oriented applications" (Fugate, 1991). Therefore, the IMIS prototype software data will be used to calibrate the Ada COCOMO model. Cost elements 1.4.1 and 1.4.2 both address the RDT&E software development costs incurred to present IETMs. They do not include the costs to convert TOs to IETM format which is covered in cost element 1.4.6.

Software estimates include the development efforts for the core system which contains the system operation module, the presentation system, the diagnostic module, the External Database Manager, and the CAMS/IMIS interface. Initial sizing estimates are included in CES 1.4, Appendix D. The Ada COCOMO model is used to determine the manhours required for development.

System Integration, Test and Evaluation. Ray's Enhanced Version of Intermediate COCOMO (REVIC) was analyzed to determine a factor for estimating the system integration, test, and evaluation (SIT&E) cost. REVIC contains a factor of 22 percent, using the software development cost as the estimating base, to estimate the cost of performing DT&E, IOT&E, and Acceptance Test. The costs estimated using these factors resulted in the cost to perform SIT&E.

Data Conversion. This element refers to the transformation of existing digital or electronic technical orders to the new IMIS environment. In the development phase, it refers to the initial effort to convert current F-16 O-Level TOs to IETMs. A per-page factor from an analogous effort from the IMIS F/A-18 demonstration was used to estimate this cost. This analogy was validated using Lockheed Fort Worth's effort on the IMIS F-16 Program.

Data. This element only includes the cost for management data. It was estimated using a historically derived factor of two percent[9] that was applied to the RDT&E cost for PME software and system integration.

Training. This element includes the costs to develop user training courses. Representative courses by type and duration (similar to the Integrated Technical Data System [ITDS] program) were used to estimate IMIS requirements. The cost estimates are based on factors from AFR 173-13, information gathered from independent training organizations, and estimated training requirements.

Investment Costs

The Investment Phase includes all costs required to fabricate, assemble, and deliver the IMIS system in quantities to support worldwide F-16 maintenance. For example, investment includes all costs related to the manufacture and delivery of usable end items, support equipment, initial training, data, and spares. Table 4 displays the cost elements for this analysis. (Appendix B contains detailed definitions for each Investment Phase cost element.) The investment cost elements encompass the cost of manufacturing or procuring components, subcomponents, and systems which are either manufactured in-house or through subcontracts. Also included in this phase are costs associated with the worldwide fielding of IMIS: site surveys, preparations, and installations at F-16 maintenance locations.

[9]This is consistent with Defense Communications Agency Circular (DCAC) 600-60-1, Table 20-1.

IMIS COST ELEMENT STRUCTURE

2.0 INVESTMENT

2.1 SYSTEMS ENGINEERING/PROGRAM MANAGEMENT

2.2 PRIME MISSION EQUIPMENT
- 2.2.1 Portable Maintenance Aid (PMA) Equipment
- 2.2.2 Maintenance Information Workstation (MIW) Equipment

2.3 SUPPORT EQUIPMENT

2.4 SOFTWARE

2.5 DATA
- 2.5.1 Technical Data/Manuals
- 2.5.2 Management Data

2.6 TRAINING
- 2.6.1 Initial Training
  - 2.6.1.1 Instructor Training Course
  - 2.6.1.2 User Training Course
  - 2.6.1.3 Maintenance Training Course
- 2.6.2 Training Manuals

2.7 INITIAL SPARES

2.8 SITE ACTIVATION/IMPLEMENTATION
- 2.8.1 Site Surveys
- 2.8.2 Site Implementation

Table 4. Investment Cost Element Structure

Table 5 outlines the Investment Phase cost-estimating methodologies. The following subsections discuss the applicable investment cost elements and the corresponding estimating methodologies.

2.0 INVESTMENT	
2.1 SYS ENG/PROG MGMT	Engineering Estimate
2.2 PRIME MISSION EQUIPMENT	Analogy/Learning Curves/Catalogs
2.3 SUPPORT EQUIPMENT	Engineering Estimate/Factor
2.4 SOFTWARE	N/A
2.5 DATA	Factors (DCAC 600-60-1)
2.6 TRAINING	Analogy/Experts/Factors
2.7 INITIAL SPARES	N/A
2.8 SITE ACTIVATN/IMPLEMENTN	Engineering Estimate/Factors

Table 5. Investment Cost Estimating Methodologies

Systems Engineering/Program Management. The SE/PM element refers to the effort during the Investment Phase for the business management and system engineering effort of the IMIS project. This element uses the same methodology as described in SE/PM for RDT&E.

Prime Mission Equipment. Hardware estimates for PME were developed from basic vendor quotes. The vendor quotes were adjusted to reflect learning curve impact on final assembly and fabrication.

- Portable Maintenance Aid. This element includes the resources necessary to produce the PMAs to meet the end user field requirement. The investment costs were estimated by defining the first unit cost, determining the learning curve, and determining the lot sizes, then applying the learning curve theory for the average cost for each lot. The results obtained from the learning curve analysis were validated using a bottoms-up engineering estimate.

- Maintenance Information Workstation. This element includes all effort associated with the production of requisite quantities of MIWs. A bottoms-up engineering methodology was used to estimate the cost of MIW hardware. For the MIW, analogous COTS hardware was identified for each component (or a system incorporating the required component capability). This analysis identified five separate configurations of the MIW, each based on needs in the area in which it will be used (see Table 6). This estimate assumes all configurations are delivered with a fully functional software package.

MIW Configuration	Stationary	Mobile	Management	Shop	DOL
Basic Unit	X	X	X	X	X
Gateway	X			X	
Unix-Lan	X		X		X
Radio Link	X	X			
CD-ROM	X	X		X	X
Module Interface Unit	X	X		X	X
Laser Printer	X			X	X
Data Storage	X				X
Power Conditioner	X				

Table 6. Maintenance Information Workstation Configuration

- Support Equipment. The element includes the support equipment that is required to support IMIS equipment. The only support items currently required are rechargeable batteries and battery rechargers for the PMA. This study assumes that, for compatibility purposes, spare batteries are purchased with the rechargers.

Data. This element refers to the documentation necessary to operate and support the IMIS system. Data consists of two elements: technical data and management data. DCAC 600-60-1 contains a data cost factor matrix that was used to develop a management data factor. This factor is applied to the acquisition cost of hardware, resulting in a cost estimate for management data. The technical data was estimated using an engineering estimate of the operations manuals required for IMIS.

Training. Training includes both instructor training and individual user training. Training costs for this phase were estimated by determining the number of personnel requiring initial training (quantity and type of training) and estimating the total resources required (instructor pay and travel--air fare, per diem, lodging, etc.). The cost estimates use data from the Federal Travel Directory, information gathered from independent training organizations, and estimated training requirements.

Initial Spares. The hardware maintenance philosophy assumes that the IMIS hardware is maintained by contractor personnel. Since contract maintenance rates include both parts and labor, no initial lay-in spares are required.

Site Activation/Implementation. The site activation/implementation element refers to the effort to conduct site surveys and install the IMIS system at operational locations. The methodology used to estimate costs includes travel cost, per diem lodging costs, and salaries of personnel associated with conducting site surveys and installation of IMIS worldwide.

Operations and Support Costs

The O&S Phase includes all costs required to operate and maintain IMIS throughout its operational life. Included are costs for managing, operating, and maintaining IMIS and for recurring training. Cost elements are identified for the functional areas associated with the maintenance of F-16 aircraft to facilitate estimating IMIS projected benefits. The F-16 base-level functional areas are TO usage, aircraft maintenance diagnostics, information systems interaction, part requisitions, and maintenance training. The IMIS O&S Phase begins with the first installation of IMIS at an F-16 maintenance location and continues through the IMIS operational life. Table 7 displays the relevant cost elements for this analysis. (Appendix B contains detailed definitions for each O&S Phase cost element.)

IMIS COST ELEMENT STRUCTURE

3.0 OPERATIONS AND SUPPORT

3.1 SYSTEM MANAGEMENT

3.2 OPERATIONS
- 3.2.1 System
  - 3.2.1.1 Utilities
  - 3.2.1.2 Consumables
  - 3.2.1.3 Transportation (2nd Destination)
- 3.2.2 Functional
  - 3.2.2.1 Technical Order Usage
  - 3.2.2.2 Aircraft Maintenance Diagnostics
  - 3.2.2.3 Information System Interaction Time
  - 3.2.2.4 Part Requisitions

3.3 HARDWARE MAINTENANCE

3.4 SOFTWARE MAINTENANCE

3.5 DATA CONVERSION

3.6 SUSTAINING INVESTMENT

3.7 TRAINING
- 3.7.1 Recurring Training
- 3.7.2 Training Course Updates

Table 7. Operations and Support Cost Element Structure

Table 8 indicates the O&S cost-estimating methodologies. The Base Case represents the current non-IMIS environment. An estimating methodology is shown for each alternative identified in Section III.

3.0 OPERATIONS AND SUPPORT	Base	Core IMIS	Core IMIS plus Part Ordering
3.1 SYSTEM MANAGEMENT	N/A	Analogy	
3.2 OPERATIONS			
3.2.1 System	N/A	Engineering Estimate/CERs	
3.2.2 Functional			
3.2.2.1 Technical Order Usage	Historical	IMIS CERs	
3.2.2.2 Aircraft Maint Diagnostics	Historical	IMIS CERs	
3.2.2.3 Info System Interaction Time	Historical	IMIS CERs	
3.2.2.4 Part Requisitions	Historical	N/A	CERs
3.3 HARDWARE MAINTENANCE	N/A	Factors/Catalogs	
3.4 SOFTWARE MAINTENANCE	N/A	Ada COCOMO	
3.5 DATA CONVERSION	N/A	Analogy/Engineering Estimate	
3.6 SUSTAINING INVESTMENT	N/A	N/A	
3.7 TRAINING	N/A	Analogy/Experts/Factors	

Table 8. Operations and Support Cost Estimating Methodologies

System Management. A cost-estimating analogy was used to estimate the program management requirements for this phase. Similar programs were reviewed and appropriate manning assumptions were developed and tailored to reflect expected IMIS program requirements.

System management costs are estimated by applying a historically derived factor to the Software Maintenance Cost Element. Based on a survey of several analogous programs, a 24 percent cost factor for system management was developed. This factor is based on the complexity of the software to be maintained.

Hardware Maintenance. The hardware maintenance element refers to the maintenance cost of the PMAs and MIWs by contract personnel. The maintenance concept for the IMIS system assumes all maintenance except BIT check and battery replacement is accomplished by on-call contractor support. The methodology for estimating the annual maintenance costs uses cost factors for on-call service rates and annual maintenance rates. COTS software maintenance fees were estimated using catalog and analogy methods.

Software Maintenance. Software maintenance includes software maintenance associated with the update and repair of the basic software (i.e., traditional software maintenance). The Ada COCOMO model was used to estimate software maintenance.

Data Conversion. After the initial data conversion during RDT&E, all TO changes will be incorporated into JCALS as Type C data. Therefore, IMIS will not incur any recurring cost for this element.

Sustaining Investment. The sustaining investment element refers to the effort to provide replenishment spares to replace items which are designated as nonrepairable. The maintenance philosophy dictates that a contractor maintains the IMIS equipment, including hardware parts and labor rates. To avoid double counting, no estimate is included for this element.

Training. Training refers to the conduct of recurring training of operational personnel to maintain IMIS proficiency, and to the resources to train new personnel due to personnel turnover. Included is the effort necessary to keep all IMIS training courses current and updated. The cost estimates use data from the Federal Travel Directory, AFR 173-13, and estimated training requirements. This methodology addresses travel, per diem, salaries, and lodging associated with the TRWG process and necessary recurring training at the organizational level.

Benefit Estimating Methodology

This section presents the benefits from Section III that were quantified and summarizes the benefit-estimating methodologies.

Although the estimates of quantifiable benefits are presented as savings, they actually represent estimates of efficiency improvements. Thus, they will not automatically convert into budgetary savings. Implementing IMIS is necessary but not sufficient to realize such savings.

Air Force leaders will need to decide how to convert process improvements made possible by IMIS to actual budgetary savings.

In discussing the IMIS benefits, the following areas will be addressed: TO Usage, Information System Interaction Time, Aircraft Maintenance Diagnostics, and Part Requisitions. Table 9 outlines the benefits that are quantified in this project. Each quantifiable benefit is further classified regarding the type of metric that was estimated: dollar value or maintenance manhours (MMHRs).

IMIS Benefits

CES#		DOLLARS	MMHR
3.2.2.1	***TO Usage***		
3.2.2.1.1	Post TO Changes	X	X
3.2.2.1.2	TO Research	X	X
3.2.2.1.3	TO Mobility	X	
3.2.2.1.4	AFTO 22 Change Requests	X	X
3.2.2.2	***Aircraft Maint Diagnostics***		
3.2.2.2.1	Maintenance Troubleshoot	X	X
3.2.2.2.2	RTOKs	X	X
3.2.2.2.3	Repair Time	X	X
3.2.2.2.4	MRSP	X	
3.2.2.2.5	Pipeline Spares Inventory	X	
3.2.2.3	***Information System Interaction Time***		
3.2.2.3.1	Maint Documentation Time	X	X
3.2.2.4	***Part Requisitions***		
3.2.2.4.1	Communications	X	X
3.2.2.4.2	Unproductive Time	X	X
3.2.2.4.3	Aircraft Cannibalization	X	X

Table 9. IMIS Quantifiable Benefits

Technical Order Usage Improvements

IMIS eliminates the requirement for the base-level technicians to maintain paper TO libraries, reduces the time required to access TO information, reduces the TO mobility transportation requirement for deployments, and reduces the time and effort to report TO errors and suggested changes.

Eliminate Need to Manually Post TO Changes. The cost/benefit of eliminating the paper-based TO library updates through IMIS implementation is calculated by determining the dollar value of the manhours saved. These numbers are calculated by using the Base Case factors escalated by the annual TO growth rate and the equivalent dollar savings per manhour.

Reduce TO Research Time. IMIS provides maintenance technicians with an integrated database, allowing them access to pertinent maintenance information without having to research multiple individual paper TOs. MMHR savings are calculated by subtracting the time to research TOs in an IMIS environment from the calculated time in the current paper-based environment, and converting to equivalent cost dollar savings by multiplying the manhours by the cost per manhour.

Reduce TO-Related Weight for Mobility. Replacing the current paper-based TO system with IMIS releases valuable airlift capacity (space/weight previously occupied by TO libraries) during deployments. The value of this released capacity is estimated by valuing the difference in weight requirements for the MIW compared to that for deployed paper TO libraries. The benefit associated with the reduced airlift requirement is best estimated by using a cost per flying hour factor.

Automate AFTO 22 Change Requests. IMIS provides maintenance technicians with automated, on-line capabilities for reporting suggested changes. This increased capability reduces the manpower necessary for submitting changes, increases the accuracy of the submissions, and ensures that vital changes and suggestions are submitted and distributed. The benefit resulting from this is derived by estimating the number of AFTO 22s submitted per year and calculating the Consolidated Technical Order Distribution Office (CTODO) manhours required to process those change requests (before and after IMIS).

Aircraft Maintenance Diagnostic Improvements

IMIS will provide an electronic dynamic diagnostic capability. IMIS provides technicians with new diagnostic routines that improve fault-isolation accuracy while also reducing maintenance time. The specific IMIS benefits to be discussed in this section are: reductions in maintenance troubleshooting times, reductions in the removal of serviceable equipment (RTOKs), reduced repair times, reduced pipeline spares, and reduced MRSP requirements.

Reduce Maintenance Troubleshooting Time. IMIS provides interactive troubleshooting guidance through software that will analyze data derived from on-board weapon system sensors, in-flight recorded data (environmental and failure), and maintenance information systems. Early IMIS demonstration tests (September 1986) indicate substantial reductions in troubleshooting time. Timeline data was collected illustrating non-IMIS versus IMIS troubleshooting performances. The benefit of IMIS implementation was calculated by estimating the total maintenance time required in the Base Case, then applying the reduction in effort using the IMIS factors. The difference in hours is converted to manyears, then to dollars.

Reduce RTOKs. IMIS test demonstrations have shown that false removal rates can be reduced substantially. As a result, maintenance manpower is reduced at both the base- and depot-levels, and transportation costs are also reduced. Benefits are realized in both the base- and depot-level repair cycles. These benefits were calculated by first estimating the number of RTOKs in the Base Case, then applying the IMIS reduction factor. The difference of these numbers is the reduction in RTOKs. This reduction was converted to savings in manhours and transportation costs. Manhours were converted to equivalent dollars and summed to provide a total benefit.

Reduce Repair Times. Data from the *Maintenance Task Timelines for Integrated Maintenance Information System - Final Task Report* (Fischer et al., 1986) was used to estimate the potential IMIS benefits. The difference in the average time to effect specified repairs both with and without IMIS was calculated to quantify the manhours saved. These manhours were then converted to dollars.

Reduce Mobility Readiness Spares Package Requirements. An MRSP is an air transportable package of spare parts required to sustain planned wartime or contingency operations. MRSP composition is based on historical trends and projections of requirements. Spare LRUs are included for potential false removals because the false removals are in the historical data. Since IMIS reduces the incidence of false removals, MRSP contents can be more realistically stocked for actual projected failures. Spares that become excess because false removals are lowered will be eliminated from the kits, thereby reducing the transportation requirement. In particular, the projected number of RTOKs is estimated based on the Base Case scenario, then compared to the projected number of RTOKs for the two IMIS alternatives. The reduction in MRSP transportation costs is calculated by comparing aircraft requirements in the Base Case to aircraft requirements with IMIS.

Reduce Pipeline Spares Inventory. Pipeline spares are LRUs and shop replaceable units (SRUs) needed to ensure that sufficient stock levels are available for the order and shipment pipeline from depot to base (demand for new/repaired items) and base to depot (demand items to be repaired). The composition of the pipeline is based on the specified repair level (base or depot) for the system's LRUs and SRUs. The composition is also based on projected failure rates (mean time between demand), acceptable level of back orders (unsatisfied demands), depot repair cycle time (DRCT), and not repairable this station (NRTS) rates.

IMIS improves maintenance diagnostic capabilities and reduces the incidence of RTOKs. A reduction in RTOKs reduces the total pipeline requirements by lowering the demand for items. The difference in the number of RTOKs between the Base Case and IMIS scenarios was multiplied by an average cost per pipeline item to determine the cost savings.

Information System Interaction Time Improvements

Timely and accurate maintenance information is paramount for today's aircraft maintenance tasks. The current maintenance environment is fraught with cumbersome, inflexible information systems. The primary benefit of IMIS in this functional area is that it *reduces maintenance documentation time* by automatically recording requisite maintenance information such as work unit codes, system operating times, part numbers, malfunction codes and repair codes. In addition, IMIS will automatically collect additional information such as employee number, skill level, and work center (Link et al. 1987).

Unpublished data from the F/A-18 IMIS Demonstration Test, June 1992, was used to determine the expected reduction due to IMIS implementation. This information was used to estimate the reduction in MMHRs by comparing non-IMIS and IMIS maintenance environments. This difference was then converted to dollars.

Parts Requisition Improvements

IMIS automates the interface to base supply, reducing maintenance times to research stock numbers and provide on-line supply queries. Supply communications are enhanced and the effects of a slow responsive environment are significantly reduced. Improved communications and reduced aircraft cannibalization are discussed below.

Communications. IMIS reduces the time spent researching and ordering parts from the aircraft location. The benefits from IMIS implementation were determined by first estimating the time spent in the Base Case to research and order parts. Then, an IMIS implementation reduction factor was applied. MMHR savings were determined by calculating the difference between the Base Case and the IMIS alternatives. MMHR savings were then converted to equivalent dollars.

Unproductive Time. Critical information is required during the maintenance process. Information such as maintenance history, applicable historical flight data, and supply information must be obtained independently through slow, nonintegrated maintenance information systems. IMIS eliminates unproductive time by integrating the required information systems and presenting requisite information in an on-line, real-time environment. IMIS preassembles the required information for timely access.

Data from the *Maintenance Task Timelines for Integrated Maintenance Information System - Final Task Report* (Fisher et al., 1986) was used to estimate the reduction in unproductive time. This difference was converted into equivalent dollars.

Reduce Aircraft Cannibalization. Decisions are sometimes made to remove parts from nondefective aircraft (cannibalized) instead of waiting for delivery of parts from supply or stock-out notifications. These actions result in additional work because the cannibalized part must be removed and replaced, and an operational check must be performed. IMIS may reduce these cannibalization occurrences and the expenditure of valuable manpower by making additional information available to the decision maker. The benefits from IMIS implementation were determined by first estimating the cost of cannibalizations in the Base Case, then determining an appropriate IMIS efficiency factor. This factor was applied to the cannibalization cost to determine the IMIS benefit.

VI. RESULTS AND DISCUSSION[10]

This section presents the results of applying the methods described in Section V. The LCC of each alternative is broken down into nonrecurring costs and recurring costs. The total LCC is then displayed in constant and present value dollars. The IMIS alternatives' LCCs were compared to the Base Case LCC to measure the relative differences between alternatives.

Nonrecurring Costs

The nonrecurring costs represent the investment that would be required by the Government to implement an alternative for the F-16 fleet. There are no nonrecurring costs associated with continuing to operate under the Base Case conditions. For the IMIS alternatives, the nonrecurring costs comprise of RDT&E and Investment costs (i.e., the costs to acquire and field IMIS). Table 10 shows these costs in FY 93 constant dollars.

Cost Element	Base Case	Core IMIS	Core IMIS plus Remote Part Ordering
RDT&E			
SE/PM	---	5.7	5.7
PME	---	**2.7**	**2.9**
Software/SIT&E	---	6.7	6.7
Data Conversion	---	54.6	54.6
Other	---	0.4	0.4
Total RDT&E	---	70.1	70.3
Investment			
SE/PM	---	3.8	3.8
PME	---	**89.1**	**93.0**
Training	---	2.5	2.5
Other	---	4.7	4.7
Total Investment	---	100.1	104.0
Total Nonrecurring	**---**	**170.2**	**174.3**

Table 10. Constant FY 93 Dollar Nonrecurring Costs ($M)

[10]This section's results differ from the interim results reported in AL/HR-TP-1993-0018 entitled, *Integrated Maintenance Information System (IMIS) Initial Estimates of System-Wide Costs and Benefits: An Executive Summary* (Burright et al., 1993). The difference is due to changes in key assumptions and updates to operational data used in the model. One assumption that was changed dealt with the number of TO pages converted to IETMs. In the May 1993 technical paper, all (over one million) F-16 TO pages were assumed to be converted to IETMs. In this report, only base-level TOs (approximately 575,000 pages) were assumed to be converted. The May 1993 technical paper also did not address the cost/benefit implications of handling classified TOs. In addition to these assumptions, more current MMHR data from MODAS and VAMOSC were incorporated into the study. Finally, the results reported in the May 1993 paper assumed a discount factor based on the OMB 1991 guidance (10%). The results in this final report reflect the most current guidance from OMB concerning discount factors (4.3%).

The largest RDT&E cost is the conversion of existing F-16 TOs into IETMs. Data conversion costs account for 78 percent ($54.6M) of the RDT&E cost. The highest schedule risk item during RDT&E is the development of the application software modules. The applications development schedule drives the RDT&E schedule for design and development of IMIS and the subsequent start of the Investment Phase of the program.

Most of the investment costs are related to the procurement of PMAs, MIWs, and their related system software to support all F-16 aircraft worldwide. PMAs account for 76 percent ($75.815M) of the investment costs. MIWs account for 13.3 percent ($13.271M) of the investment cost. Other major investment costs are required to perform the initial training of all end-users of the system.

The only cost difference between Core IMIS and the Remote Part Ordering alternative is in the purchase of PME. As stated in Section V, this difference is due to the requirement for additional hardware to support the RF link between the PMA and MIW.

Recurring Costs

The recurring costs represent both the ADP costs for O&S of IMIS and the functional cost of performing the F-16 maintenance mission. Table 11 displays these costs in FY 93 constant dollars.

Cost Element	Base Case	Core IMIS	Core IMIS plus Remote Part Ordering
ADP O&S			
System Operations	---	5.1	5.1
H/W Maintenance	---	**42.0**	**42.9**
S/W Maintenance	---	8.5	8.5
Other	---	3.6	3.6
Total ADP O&S	---	59.2	60.1
Functional O&S			
TO Usage	587.1	67.0	67.0
Aircraft Maint Diag.	1,173.8	799.3	799.3
Info Sys Interaction	16.3	7.2	7.2
Part Requisitions	**55.1**	**55.1**	**20.7**
Total Functional O&S	1,832.3	928.6	894.2
Total Recurring O&S	**1,832.3**	**987.8**	**954.3**

Table 11. Constant FY 93 Dollar Recurring Costs ($M)

Recurring Automated Data Processing Operations and Support Costs

The recurring ADP costs associated with each alternative represent the total ADP O&S costs that would be incurred by the Government following the implementation of an alternative.

There are no recurring ADP costs under the Base Case conditions. Most of the ADP O&S costs are associated with the repair and maintenance of IMIS hardware and software. The hardware costs reflect a maintenance concept which employs on-call contractor support for all repair actions except BIT check and battery replacement. The software costs reflect normal update and repair of the applications software. The recurring purchase of PMA batteries to replace the original batteries after their life cycle has been consumed accounts for the majority of the system operation costs.

Recurring Functional Operations and Support Costs

The recurring functional O&S costs associated with each alternative represent the essential functional activities directly related to the base-level repair of F-16 aircraft. In the Base Case, these costs reflect the cost of continuing to perform the maintenance mission without IMIS. For the IMIS alternatives, these costs reflect the impact of using IMIS to perform maintenance functions (i.e., the residual functional costs to perform the maintenance mission based on implementing IMIS). Therefore, the difference between the Base Case and the IMIS alternatives functional costs result in the functional benefits of IMIS.

IMIS Functional Benefits

The following paragraphs summarize the functional benefits associated with the IMIS alternatives. The IMIS life-cycle benefits are expressed in FY 93 constant dollars.

Core IMIS Functional Benefits ($903.8M)

The functional benefits associated with the Core IMIS capabilities are achieved through improvements in the functional areas of TO usage, aircraft maintenance diagnostics, and information system interaction.

Technical Order Usage ($520.1M)

Eliminate the manual-posting of TO Changes ($454.5M).
- Reduce TO Research time by 50 percent ($61.3M).
- Reduce the weight required to support squadron mobility by over 90 percent ($3.0M).
- Reduce the effort to prepare and submit AFTO 22 Change Requests by 20 percent ($1.3M).

Aircraft Maintenance Diagnostics ($374.5M)

- Reduce maintenance troubleshooting time by 20 percent ($4.9M).
- Reduce the number of RTOKs by 30 percent ($172.2M).
- Reduce repair time by 42.4 percent ($84.9M).
- Reduce the number of RTOK items in MRSPs by 30 percent ($36.8M).
- Reduce the number of RTOK items in the pipeline spares inventory by 30 percent ($75.7M).

Information System Interaction ($9.2M)

- Reduce time to document maintenance actions by 56 percent ($9.2M).

Core IMIS Plus Remote Part Ordering Functional Benefits ($938.2M)

This alternative combines the Core IMIS benefits for Aircraft Maintenance Diagnostics, Technical Order Usage, and Information System Interaction with the benefits associated with the Remote Part Ordering capability. The Base Case part requisition cost of $55.1M compared to $20.7M for this IMIS alternative yields $34.4M of functional benefits. The $903.8M of benefits for Core IMIS combined with the $34.4M for the Remote Part Ordering capability results in total functional benefits of $938.2M for Core IMIS plus Remote Part Ordering. The incremental benefits associated with this option are achieved through the following functional improvements.

- reducing time spent awaiting supply information by 67 percent ($19.2M).
- eliminating unproductive time ($14.7M).
- reducing aircraft cannibalization by five percent ($0.5M).

Total Life-Cycle Costs

This section summarizes the total LCC of the Base Case and the IMIS alternatives in FY 93 constant dollars and present value dollars. The present value estimates were computed using uniform annual cost which is the average discounted cost per year. Present value estimates support comparison of alternatives by normalizing the costs when the life-cycle phases are distributed over different calendar periods. Figure 2 displays these estimates for the Base Case, Core IMIS, and Core IMIS plus Remote Part Ordering.

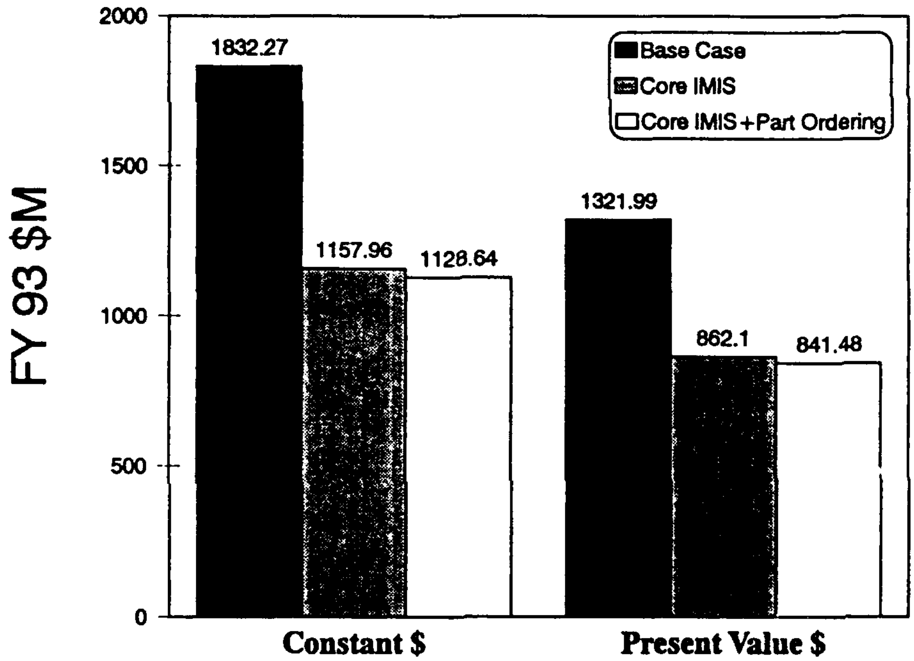

Figure 2
Constant Dollar and Present Value LCC Results

Based on the LCC results displayed in Figure 2, IMIS is cost effective. Core IMIS provides net savings on the order of $674.3M. Adding the capability to order parts from the flightline results in additional net savings of $29.3M for a total of $703.6M. Eliminating the requirement to manually post TO changes accounted for 50 percent ($454.5M) of the IMIS benefits. Achieving these savings requires reductions in RTOKs and increases in maintenance personnel productivity.

Eliminating the hand-posting of TOs provides the largest benefits; however, the analysis is most sensitive to the assumed percent reduction in RTOKs. As noted in Section III, previous tests of electronic diagnostics technology have consistently demonstrated large reductions in false removals (as high as 100 percent). For this study, assuming a 30 percent reduction resulted in functional benefits totaling $284.7M. Figure 3 shows the impact of varying this key assumption on the net savings in LCC due to implementing IMIS.

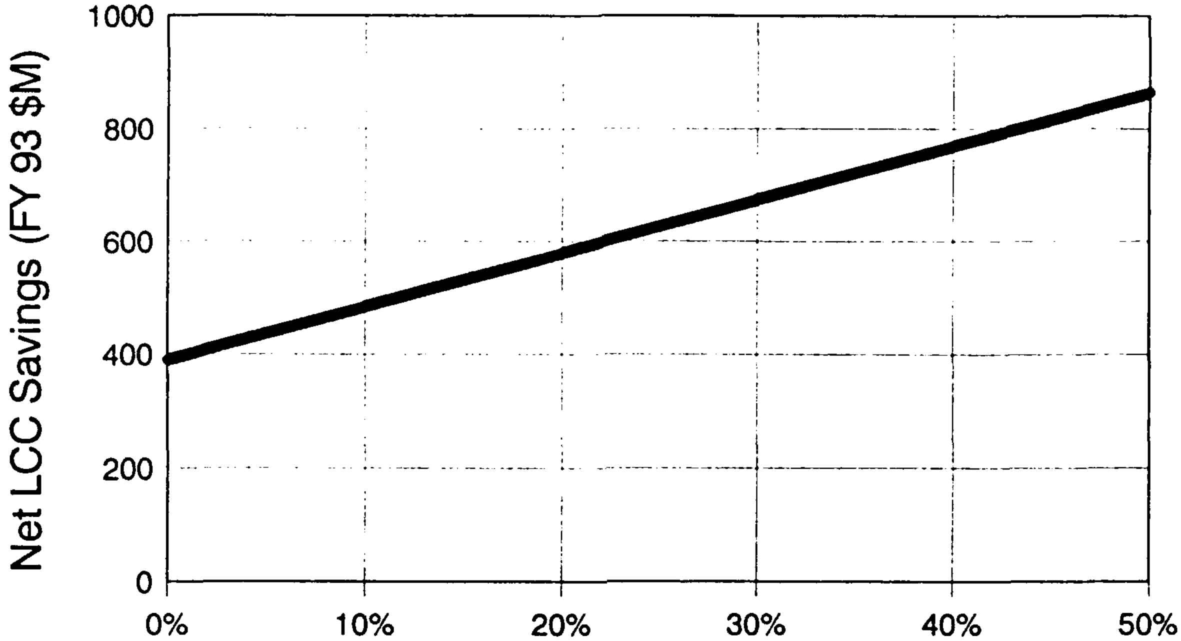

Figure 3
Retest OK Reduction Factor Parametric

VII. CONCLUSIONS

The purpose of this study was to investigate the financial impact of implementing IMIS on legacy USAF weapon systems. The F-16 was chosen as a representative system for study purposes. ROM estimates were developed for the Base Case, Core IMIS (IETMs, maintenance data system connectivity, and dynamic diagnostics capabilities), and Core IMIS plus the Remote Part Ordering option. These benefits supported the calculation of the net savings for the IMIS alternatives. The results of the study support the following conclusions.

- **IMIS is cost effective.** A conservative estimate is that implementing Core IMIS on the F-16 fleet would generate a net LCC savings of approximately $674.3M (FY 93 constant) over an eight-year life cycle.

- **Reducing the frequency of RTOKs and improving the TO library maintenance process produce the majority of IMIS benefits.** These two benefits accounted for 82 percent of the total IMIS benefits. Realizing these benefits requires the implementation of the Core IMIS capabilities.

- **PMA procurement, TO conversion, and recurring IMIS maintenance costs are the primary cost drivers**. Procurement of the PMA ($75.8M) and conversion of F-16 base-level TOs to IETMs ($54.6M) are the largest nonrecurring costs. Together, they account for 77 percent of the nonrecurring cost. Repair and maintenance of the hardware and software for IMIS account for 85 percent ($50.5M) of the recurring costs. Together, these three cost elements comprise 79 percent of the overall IMIS LCC.

- **The addition of the Remote Part Ordering capability to IMIS would contribute another $29.3M (FY 93 constant) to the IMIS net LCC savings.** The addition of the RF link to the PMA (which provides the ability to order parts directly from the flightline) adds approximately $5.1M (FY 93 constant) to the IMIS implementation cost, but yields an additional $34.4M (FY 93 constant) in benefits.

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ACRONYMS AND ABBREVIATIONS

ADP	Automated Data Processing
AFB	Air Force Base
AFLC	Air Force Logistics Command
AFR	Air Force Regulation
AFTO	Air Force Technical Order
AFTOMS	Air Force Technical Order Management System
AL	Armstrong Laboratory
ALC	Air Logistics Center
ATTD	Advanced Technology Transition Demonstration
BIT	Built-In Test
CAMS	Core Automated Maintenance System
CES	Cost Element Structure
CER	Cost Estimating Relationship
CND	Cannot Duplicate
COCOMO	Constructive Cost Model
CONUS	Continental United States
COTS	Commercial Off-The-Shelf
CTODO	Consolidated Technical Order Distribution Office
DCA	Defense Communications Agency
DCAC	Defense Communications Agency Circular
DoD	Department of Defense
DODI	Department of Defense Instruction
DOL	Dispersed Operating Location
DRCT	Depot Repair Cycle Time
DT&E	Developmental Test and Evaluation
ECM	Electronic Counter Measures
FOC	Full Operational Capability
FY	Fiscal Year
GSA	General Services Administration
HRGO	Logistics Research Division, Operational Logistics Branch
IETM	Interactive Electronic Technical Manual
IMIS	Integrated Maintenance Information System
IOT&E	Independent Operational Test and Evaluation
ITDS	Integrated Technical Data System
IV&V	Independent Verification & Validation

JCALS	Joint Computer-aided Acquisition & Logistic Support
JUSTIS	Joint Uniformed Services Technical Information System
LAN	Local Area Network
LCC	Life-Cycle Cost
LRU	Line Replacable Unit
M	Millions
MIL-STD	Military Standard
MIW	Maintenance Information Workstation
MMHR	Maintenance Manhour
MODAS	Maintenance & Operational Data Access System
MRSP	Mobility Readiness Spares Package
NPRDC	Navy Personnel Research & Development Center
NRTS	Not Repairable This Station
NSN	National Stock Number
O&S	Operations and Support
OASD	Office of the Assistant Secretary of Defense
OMB	Office of Management and Budget
OPM	Office of Personnel Management
OSD	Office of the Secretary of Defense
PA&E	Program Analysis and Evaluation
PAA	Primary Authorized Aircraft
PACAF	Pacific Air Force
PMA	Portable Maintenance Aid
PME	Prime Mission Equipment
PMO	Program Management Office
RDT&E	Research, Development, Test and Evaluation
REMIS	Reliability and Maintainability Information System
REVIC	Ray's Enhanced Version of Intermediate COCOMO
RF	Radio Frequency
RFP	Request for Proposal
ROM	Rough Order-of-Magnitude
RTOK	Retest OK
SBSS	Standard Base Supply System
SE/PM	Systems Engineering/Program Management
SIT&E	System Integration, Test, and Evaluation
SRU	Shop Replaceable Unit
TO	Technical Order
TRWG	Training Work Group
TICARRS	Tactical Interim CAMS and REMIS Reporting System

USAFE	U.S. Air Forces Europe
VAMOSC	Visibility and Management of Operating and Support Cost

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